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CONTRACT NAS 8-35817

STUDY OF HIGH PERFORMANCE ALLOY ELECTROFORMING

FOURTEENTH MONTHLY TECHNICAL PROGRESS NARRATIVE

JANUARY 28, 1985 TO FEBRUARY 22, 1985

ELECTROFORMING OPERATIONS DEPARTMENT

BELL AEROSPACE TEXTRON

POST OFFICE BOX ONE

BUFFALO, NEW YORK 14240

BY

G. A. MALONE

MARCH 11, 1985

PREPARED FOR:

GEORGE C. MARSHALL SPACE FLIGHT CENTER

MARSHALL SPACE FLIGHT CENTER, AL 35812

STUDY OF HIGH PERFORMANCE ALLOY ELECTROFORMING

ABSTRACT

More panels electroformed with intentional variations of pulse plating parameters are in work. Pulse plating frequency has been noted to have a significant effect regarding mechanical properties. The use of a high pulse frequency (assuming fixed duty cycles) results in an increase in ductility and a decrease in ultimate and yield strengths. We are currently electroforming to intermediate frequencies to obtain the best possible combination of ductility and strength. Results of some tests from high frequency specimens are tabulated. The subscale mandrel design for Phase B is ready for review. A progress review will be held with MSFC personnel in early April.

I. INTRODUCTION

The purpose of this work is to develop and demonstrate a system for electroforming materials with improved strength and high-temperature properties. The Space Shuttle Main Engine employs a main combustion chamber (MCC) where final combustion of propellant at high temperature and pressure takes place. This critical component must be structurally supported by a nickel-base alloy jacket. Producing this jacket from formed wrought metal segments requires numerous weldments which alter the mechanical properties of the base metal through heat affected zones. This requires thickening the alloy where joints are to be made to meet the structural requirements of the shroud. The use of electroformable alloys with great strength would have the potential for simplifying fabrication procedures for structural jackets and reducing overall weight by removing weldments. Such an electroformable alloy might also afford a possible use in advanced engines where light weight and good strength at high temperatures are necessary.

II. TECHNICAL PROGRESS SUMMARY

A. Task I - Literature Survey (Phase A) - Previously completed.

B. Task II - Alloy Characterization and Optimization (Phase A)

In our nickel-manganese alloy optimization studies, we have narrowed the required ranges of manganese content, electrolyte temperature, pH, and current density for producing a heat treatable material competitive with Inconel 718 and far superior to electroformed nickel. Our baseline test results on which the present optimization/heat treatment studies are based were those obtained from Specimens NM-25, NM-26, and NM-27. The results are again summarized in Table I. It is interesting to note that the ultimate strengths and yield strengths increase dramatically as the pulsed peak current density increases (the average current density stays constant). However, elongation decreases inversely to yield strength as would be expected. We have also noted that the pulse current "off" times are fairly long. Equally interesting is the observation that (1) NM-27 had slightly less manganese present than NM-26, (2) NM-27 was electroformed

TABLE I - FABRICATION AND TEST DATA FOR SPECIMENS NM-25, 26, & 27

Sample Number	Pulse Plating Information	Deposited Alloy Data	Strip No.	Heat Treatment	Test Temp(°F)	Mechanical Properties (psi) Ultimate	Yield	Elong.(%)
NM-25	Duty Cycle 50%	Panels 2 Each	NM-25A	None	Ambient	182,000	136,285	10.0
	Pulse On 20.0 msec	Size 4.38" x8.12"	NM-25B	600°F(24 Hr)	Ambient	186,825	156,160	10.0
	Pulse Off20.0 msec	Mn Comp. 3580 ppm	NM-25C	650°F(24 Hr)	Ambient	185,675	159,025	11.0
	Peak C.D. 40.0 ASF	S Comp. 24.1 ppm	NM-25D	800°F(4 Hr)	Ambient	178,110	158,885	10.0
	Avg. C.D. 20.0 ASF	Flatness Fair	NM-25E	500°F(72 Hr)	300°F	159,845	128,115	10.0
	Avg. Volts 3.9	Thickness.0685 in	NM-25F	500°F(72 Hr)	500°F	138,265	100,895	11.0
		to .0690 in.	NM-25G	650°F(24 Hr)	300°F	168,195	135,120	6.0
			NM-25H	650°F(24 Hr)	500°F	136,980	107,100	11.0
NM-26	Duty Cycle 40%	Panels 2 Each	NM-26A	None	Ambient	211,745	152,310	5.0
	Pulse On 20.0 msec	Size 4.38" x8.12"	NM-26B	600°F(24 Hr)	Ambient	226,020	198,495	8.0
	Pulse Off30.0 msec	Mn Comp. 5122 ppm	NM-26C	650°F(24 Hr)	Ambient	225,685	202,095	7.5
	Peak C.D. 50.0 ASF	S Comp. 32.0 ppm	NM-26D	800°F(4 Hr)	Ambient	214,735	197,790	7.0
	Avg. C.D. 20.0 ASF	Flatness Fair	NM-26E	700°F(24 Hr)	Ambient	190,900	163,635	19.5
	Avg. Volts 3.9	Thickness.0700 in	NM-26F	700°F(24 Hr)	300°F	180,125	141,100	6.0
		to .0704 in.	NM-26G	700°F(24 Hr)	500°F	168,080	127,195	9.0
			NM-26H					(1 in)
NM-27	Duty Cycle 25%	Panels 2 Each	NM-27A	None	Ambient	241,480	177,642	BOG
	Pulse On 10.0 msec	Size 4.38" x8.12"	NM-27B	600°F(24 Hr)	Ambient	292,655	242,025	4.5
	Pulse Off30.0 msec	Mn Comp. 4950 ppm	NM-27C	650°F(24 Hr)	Ambient	281,895	257,485	6.0
	Peak C.D. 80.0 ASF	S Comp. 48.8 ppm	NM-27D	800°F(4 Hr)	Ambient	266,340	217,030	6.0
	Avg. C.D. 20.0 ASF	Flatness Poor	NM-27E	700°F(24 Hr)	Ambient	235,980	207,785	5.8
	Avg. Volts 3.8	Thickness.0680 in	NM-27F	700°F(24 Hr)	300°F	199,940	157,845	BOG
		to .0690 in.	NM-27G	700°F(24 Hr)	500°F	Sample broke in machining		
			NM-27H					(1 in)

at the same average current density as NM-26, but NM-27 was also plated at a higher peak current density, and (3) NM-27 exhibited significantly higher ultimate and yield strengths than did NM-26.

In the current, and expected final, study of Phase A we are examining pulse plating parameters that will compromise the mechanical properties of the specimens in Table I to achieve better ductility in combination with the excellent strength features of the alloys. It was observed that all pulse "off" times for the Table I specimens were long - 20 to 30 milliseconds. We have evaluated shortening this "off" to determine if more uniform manganese dispersion is obtained and better ductility encountered. Test results obtained in this reporting period for these new specimens indicate that excellent elongations are being obtained (even with heat treatments of 260°C for 72 hours), but the ultimate and yield strengths are drastically reduced. The pulse "off" times were 2.0 milliseconds. We will be electroforming samples similar to NM-26 and NM-27 with pulse "off" times of about 12.0 milliseconds and various peak current densities from 40 to 80 ASF.

Heat treatments being evaluated on these specimens are "as deposited", 500°F(72 hours), 550°F(72 hours), 600°F(24 hours), 600°F(48 hours), 650°F(24 hours), and 700°F(24 hours). Once we have obtained sufficient comparative data for the effects of these heat treatments on mechanical properties for the new pulse frequencies being used, a full table of test results will be provided.

C. Task I - Heat Treatment of Alloy Structural Shell (Phase B)

Most of this effort has been moved under Phase A, Task II to complete optimization of the alloy resulting from various heat treatments and has been discussed above.

D. Task II - Tooling for EF of Prototype SSME (Phase B)

The subscale MCC mandrel design and drawing is complete and will be reviewed with MSFC personnel during our planned visit to review progress in early April.

III. CURRENT PROBLEMS

The primary problem at this time is the rate of electroforming of the variety of specimens required to final optimize pulse parameters and heat treatments. To alleviate this problem we are setting up a second nickel-manganese electroforming facility operated at the same chemistry and deposition parameters as the first tank. This will allow metallurgical personnel to prepare specimens in large single groups rather than many small batches.

IV. WORK PLANNED

1. Complete second small scale nickel-manganese electroforming facility. Check product for precision of duplicating results from original electrolyte in first facility.

2. Complete intermediate pulse freouency samples at selected peak current densities and average current densities.

3. Perform "as deposited" and 260°C (72 hour) heat treatment tests for mechanical properties at room temperature.

4. Visit MSFC for review of progress to date.

V. FINANCIAL DATA

See attached NASA Form 533P. Note that the most recent schedule change and funding addition (subscale mandrel fabrication) are included. Although approval to start Phase B has not been requested, charges against Phase B funding have been made to (1) complete alloy optimization studies and (2) to design and purchase material for the subscale mandrel. Both efforts have been discussed with the MSFC-COR and concurrance obtained verbally.

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MONTHLY CONTRACTOR FINANCIAL MANAGEMENT PERFORMANCE ANALYSIS REPORT

Form Approved
Budget Bureau No. 104-R0011

2. REPORT FOR PERIOD ENDING AND NUMBER OF OPERATING DAYS: February 22, 1984 (20 Operating Days)

TO: PROCUREMENT OFFICE
GEORGE C. MARSHALL SPACE FLIGHT CENTER
MARSHALL SPACE FLIGHT CENTER, ALABAMA 35812

FROM: NIAGARA FRONTIER OPERATIONS
BELL AEROSPACE TEXTRON
POST OFFICE BOX ONE, BUFFALO, NY 14240

3. CONTRACT VALUE: a. COSTS $ 189,454 — b. FEE $ 22,064

1. DESCRIPTION OF CONTRACT
a. TYPE: Cost-Plus-Fixed-Fee
b. CONTRACT NO. AND LATEST DEFINITIZED AMENDMENT NO.: NAS 8-35817
c. SCOPE OF WORK: Study of High Performance Alloy Electroforming
d. AUTH. CONTR. REP. (Signature): [signature] — DATE: February 12, 1985

4. FUND LIMITATION: $
5. BILLING: a. INVOICE AMTS BILLED $ — b. TOTAL PYTS REC'D $

CUM. COSTS/HOURS THROUGH CURRENT PERIOD

6. REPORTING CATEGORY	7. PLANNED VALUE OF WORK: SCHEDULED a.	7. ACCOMPLISHED b.	8. ACTUAL COSTS/HOURS	9. VARIANCE: SCHEDULE (Col 7b–7a) a.	9. VARIANCE: COSTS/HOURS (Col 7b–8) b.	10. CONTRACTOR'S ESTIMATED FINAL COST	11. b. TECH. % COMPLETED
PHASE A							
Task I - Literature Review							100.0
Hours	112.5	136.1	136.1	+ 23.6			
Dollars	6,998	6,652	6,652	- 346		6,652	
Task II - Alloy Characterization & Optimizat.							89.0
Hours	1,314.7	1,166.5	1,166.5	- 148.2			
Dollars	79,053	70,122	70,122	- 8,931		79,053	
PHASE B							
Task I - Heat Treatment of Alloy Struct. Shells							8.8
Hours	60.0	29.0	29.0	- 31.0			
Dollars	3,608	1,670	1,670	- 1,938		18,934	
Task II - Tooling for EF of Prototype SSME							17.5
Hours	42.0	31.0	31.0	- 11.0			
Dollars	2,525	1,786	1,786	- 739		10,202	
Task III - Prototype MCC Prep. for Electroform'g							0.0
Hours	0.0	0.0	0.0	0			
Dollars	0	0	0	0		37,868	
Task IV - Electroforming Operations/Final Report							0.0
Hours	0.0	0.0	0.0	0			
Dollars	0	0	0	0		33,134	

11. TECHNICAL ASSESSMENT OF PROGRESS — a. SCHEDULE AND STATUS

1984: J F M A M J J A S O N D — 1985: J F M A M J J A S

NASA FORM 533P SEP 71

Baseline Plan Identification (Col. 7a): Revision No.______, Dated ______.

NASA APPROVED SCHEDULE
CONTRACTOR'S WORKING SCHEDULE

NASA APPROVED SCHEDULE DATE______

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6. REPORTING CATEGORY	7. PLANNED VALUE OF WORK: SCHEDULED a.	7. ACCOMPLISHED b.	8. ACTUAL COSTS/HOURS	9. VARIANCE: SCHEDULE (Col 7b-7a) a.	9. VARIANCE: COSTS/HOURS (Col 7b-8) b.	10. CONTRACTOR'S ESTIMATED FINAL COST	11. TECHNICAL ASSESSMENT OF PROGRESS: a. SCHEDULE AND STATUS	b. % TECH. COMPLETED
SUB-TOTAL								42.3
Hours	1,529.2	1,362.6	1,362.6	- 166.6				
Dollars	92,184	80,230	80,230	- 11,954		189,454		
FIXED FEE DOLLARS	5,870	5,109	5,109			12,064		
TOTAL FUNDING REQUIRED								42.3
Hours	1,529.2	1,362.6	1,362.6					
Dollars	98,054	85,339	85,339			201,518		

NASA FORM 533P SEP 71

Baseline Plan Identification (Col. 7a): Revision No. ______, Dated ______.

NASA APPROVED SCHEDULE
CONTRACTOR'S WORKING SCHEDULE

NASA APPROVED SCHEDULE DATE ______